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This report uses the Equipment Records and Parts Specialist (76C10) Course to present a method for planning cost-effective automation of Army classroom training. Average costs per trained soldier were collected. Because almost all costs in this course vary with the length of time for training, cost-effective automation is described as more efficient use of classroom time. The analysis includes a description of current Army policy as it lowers the cost of future computer applications by equipping classrooms with computers for hands-on simulation of automated job tasks.

Classroom cost and productivity curves are defined, hour by hour, during lock-step instruction and then combined to define marginal cost per trained soldier. Classroom costs are calculated from existing budgetary data, but productivity is empirically measured. The analysis estimates cost savings if instructional software can shorten training time

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Cost-Effective Automation of Army Classroom Training: A Case Study

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September 1988

United States Army
Research Institute for the Behavioral and Social Sciences

U.S. ARMY RESEARCH INSTITUTE
FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency Under the Jurisdiction of the Deputy Chief of Staff for Personnel

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FOREWORD

The Logistics Training Technologies Technical Area of the Army Research Institute for the Behavioral and Social Sciences (ARI) is engaged in research and development to increase Army Training effectiveness by implementing improved instructional methods and advanced technology. To meet this requirement, a cooperative Training Technology Transfer Program has been established with the U.S. Army Quartermaster School, Fort Lee, VA. The objective of this program is to identify and test candidate training technologies and strategies and to institutionalize those that prove effective for Quartermaster skills training.

This report presents a method to plan and evaluate the automation of Army classroom training and uses the Equipment Records and Parts Specialist Course for a case study. It illustrates how cost and effectiveness data may be used to target computer applications to have the greatest impact on training time and cost.

This report was made possible by the Congressional Office of Technology Assessment, which made the author available on an interagency detail to the Army Research Institute to accomplish this work.

COST-EFFECTIVE AUTOMATION OF ARMY CLASSROOM TRAINING: A CASE STUDY

EXECUTIVE SUMMARY

Requirement:

To develop a cost-effectiveness method for automation of Army classroom training and to apply this method to the Equipment Records and Parts Specialist (76C10) Course.

Procedure:

Average costs per trained soldier were collected and used to develop cost-effectiveness strategy. The lock-step training process in the course was modeled in terms of marginal (hour by hour) cost and product curves, per classroom, and in terms of different training costs for faster and slower students. Current policy for automation of hands-on training was reviewed as it increases training time and cost and as it reduces costs for incremental instructional applications of existing classroom computers.

Findings:

On the average, it costs about $7,500 to train an Equipment Records and Parts Specialist for 10-11 weeks, with over 95% of costs tied to course length. This suggests that the most powerful way to reduce costs would be to shorten training time. The cost breakdown also shows that technical instruction accounts for only 14% of total costs. This relatively low-cost share means that a large percentage increase in cost for technical instruction causes a much smaller percentage increase in total cost and that improved instruction may reduce almost all other training costs by shortening training time.

Each day of training time saved, via improved instructional technology, saves $425,000. If new instructional software has a useful lifetime of 3 years, than a $1 million investment in software would increase total training costs by less than 2%, while it would increase inputs for technical instruction by about 33%. Classroom productivity curves are used to target instruction blocks in which improved instruction is most likely to shorten required training time.

Utilization of Findings:

The method can be used to estimate the effects and costs of current classroom training and future automation options. With appropriate cost and productivity data, the analysis targets optimal classroom applications of computers in the 76C10 course and in other Army courses that employ lock-step instruction and use computers for hands-on simulation of automated job tasks.

COST-EFFECTIVE AUTOMATION OF ARMY CLASSROOM TRAINING: A CASE STUDY

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COST-EFFECTIVE AUTOMATION OF ARMY CLASSROOM TRAINING:
A CASE STUDY

INTRODUCTION AND SUMMARY

The paper begins with a review of average training costs, per soldier, for the Equipment Records and Parts Specialist Course, known as 76C10, at the Quartermaster School (QMS) in Fort Lee, Virginia. The current 76C10 Course costs about $7500 per graduate for 10-11 weeks of training. This average cost is broken down into major cost components using the Cost Element Structure (CES) Model (Knapp and Orlansky, 1983). The CES breakdown has two major implications for cost effectiveness strategy. First, since course length determines over 95% of cost, the most powerful way to reduce costs would be to shorten the Course. Second, since costs for technical instruction amount to a small share (14%) in total cost, a large percentage increase in outlays for technical instruction accounts for a much smaller percentage increase in total training cost. At the same time, if new instructional inputs shorten required training time, these increased outlays may leverage larger savings in total training cost.

Cost effectiveness methodology is presented next. Classroom training in the 76C10 Course is modeled as a dynamic production process in which costs can be attached to inputs and value imputed to the existing performance criteria. Classroom cost and productivity are defined hour by hour. Cost structure is considered first because the data have been collected for administrative purposes. The analysis leads to the conclusion that saving one hour of actual training time, for all 75 classes during one year, saves about $425,000. Saving one day of training lowers annual training costs by over $1,000,000.

Classroom productivity is defined as the number of soldiers meeting the current test-based performance criterion hour by hour during an instruction block. Productivity varies over time because some soldiers learn faster than others. Productivity curves vary across different blocks of instruction because some subject matter is easier to learn than others. Both differences, among soldiers and subject matter, can be used to target when and where automation and other instructional program changes may result in greatest reductions in training time and thus result in greatest cost savings.

At this point, the discussion shifts to policy for classroom automation. Current policy dictates that classrooms will be automated to permit hands-on simulation of tasks that are automated in the field. This policy is demonstrated in terms of a 3-week extension to the 76C10 Course when about 10% of Course graduates train on the Tactical Army Combat Support Computer System/Standard Army Maintenance System (TACCS/SAMS). The costs of this existing automated training system are presented in terms of the Training Cost Breakdown Structure (TCBS) (Seidel and Wagner, 1977). The analysis shows that automation for hands-on simulation marginally increases training costs per week of training while it substantially increases total cost by extending training time.

The final section combines methodology and policy to describe cost effective options for classroom automation. The policy perspective includes fiscal constraints which motivate cost effectiveness concerns in the first place. Cost effective options for automation are described as small increments or add-ons to existing hands-on software. Although "hands-on add-ons" are not presently being considered at the QMS, the argument is made that they may prove cost effective compared to current attempts to meet fiscal constraints by cutting back on instructional staff.

AVERAGE TRAINING COSTS

Cost effectiveness analysis for current military training generally starts with cost analysis because cost data are typically more available and reliable than effectiveness data. Following Army Training and Doctrine Command (TRADOC) policy, the Quartermaster School (QMS) at Fort Lee, Virginia collects training cost data on an annual basis. In Table 1, fiscal 1987 cost data for the Equipment Records and Parts Specialist Course (76C10) are divided by the total number of 76C10 graduates for the same year (3000) to obtain average training costs per soldier.

Table 1 employs the Cost Element Structure (CES) Model (Knapp and Orlansky, 1983).[1] Before looking at the data, certain characteristics of this cost taxonomy are worth noting. While the CES model divides costs into 3 time periods (i.e. Research and Development, Initial Investment, and Operating and Support), this analysis of current technology need not include the R&D nor initial investment costs because they were sunk many years ago. Furthermore, several CES sub-categories for Operating and Support do not apply because the 76C10 Course presently uses very little hardware and conducts very little activity outside of the classroom (e.g., costs for petroleum and ammunition are minimal). Finally, no distinction is made here between military and civilian personnel costs, nor among a large number of indirect costs associated with running the entire Fort Lee installation. Cost data are aggregated across these distinctions because by and large they would not be directly affected by contemplated changes in technical instruction, including classroom automation.

The Cost Driver

Two main economic conclusions may be drawn from these average cost data. The first involves the economic importance of the time spent by trainees in the classroom and thus in residence at Fort Lee (Table 1). Trainee residence time directly determines their pay and allowances (40% of total costs) and indirectly determines the share of Fort Lee "base operations" and related support costs allocated to 76C10 training (37%). "Base operations" reflects overhead expenses at Fort Lee that are charged on the basis of the number of 76C10 soldiers in residence (the "student load"). The longer the Course, given a fixed graduation requirement, the greater the number of soldiers in residence and thus the larger the share of total Fort Lee base operations costs charged to 76C10 Course.

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1. Current methodology for military cost and training effectiveness analysis (CTEA) provides an extensive accounting structure to identify and classify training costs. The CES model and the TCBS model (Seidel and Wagner, 1977) are both used in this Report for cost analysis. The CES model is used to examine costs of current 76C10 training because it incorporates training process into conventional cost accounting in the the Military. The TCBS model is used later to examine automation costs because it is designed specifically to deal with new training technology. For an extensive literature review and critical appraisal of CTEA models, see Adams, Goldberg, and Rayhawk (1986). For additional critical perspective see Soloman (1986).

Table 1

76C10 Training Costs Per Graduate
During FY87

Cost Category	Data Source	$ per Student*	Cost Share
A. Direct Instruction	Supply Dept./QMS		
1. Pay and Allowances			
a. Instructors		900	12%
b. Supervisors, Adm, and Supp.		60	1%
2. Instructional Materials		40	1%
B. Other Training Costs			
1. Battalion	Supply Dept./QMS	300	4%
2. Directorate of Training and Development (DOTD)	TRADOC	300	4%
C. Soldier/Trainee Costs			
1. Pay, Allowances Other	Supply Dept./QMS	3000	40%
2. PCS (Travel to Fort Lee)	AMCOS Model/ARI	100	1%
D. Indirect Costs	TRADOC		
1. Base Operations		2400	32%
2. Other Support		400	5%
Total		7500	100%

* Actual numbers have been rounded off because greater precision would not significantly change cost shares.

Since course length determines how many soldiers must be trained at any one time by resident staff, it also determines pay and allowances for instructors and their supervisory and support staff (13%), battalion training costs (4%), and instructional materials costs (1%). Only about 5% of training cost can not be directly tied to residence time, student travel (1%) and the Directorate of Training and Development (DOTD)(4%). But, out of that, DOTD outlays are to some extent charged as overhead to the Course on the basis of student load.

In summary, over 95% of training costs in this Course will increase or decrease depending upon training time. By itself, this economic reality suggests that attempts to control or reduce training costs should focus upon factors that determine Course length.[2] If indeed the primary purpose of advanced individual training (AIT) in 76C10 is to train technical skills, then the instructional resources and procedures employed in the classroom should be a primary focus for cost saving because they determine the class time necessary to learn technical skills.

Leveraging Inputs to Technical Instruction

The average cost data also suggest a second economic reason to focus on inputs to technical training. This reason involves the relatively low share in total training cost that can be charged to direct (or technical) instruction (14%). From the viewpoint of potential upgrades in the design and implementation of technical instruction, this small cost share represents an economic opportunity. It means that a relatively large percentage increase in instructional costs results in a much smaller increase in total course costs. At the same time, if improved instructional inputs reduce the time necessary to learn technical skills, then the net result may be an overall cost savings as Course length declines and along with it most other training costs.

In other words, to the extent that time requirements for technical training determine Course length, the current relatively small cost share for technical instruction creates economic leverage for new inputs to technical training, including new training technology. If greater inputs or new technology can make technical training more productive in terms of learning per unit of time, then such outlays may pay for themselves. This leverage will be further explored below in terms of dollar savings per hour and per day that training time is reduced, and then in terms of when during the Course it would be easiest to shorten training time.

The Limits of Current Methods for Classroom Cost-Effectiveness

Average training cost per soldier gives a useful snapshot of the Course, but such data do not permit comparisons of costs and effects that are essential for cost effectiveness analysis. The conventional way to make such comparisons in training research is to conduct experiments. The

2. Shortening training time also has the salutary effect of increasing the number of trained soldiers on the job, given any fixed Army budget for personnel.

current Course and a new training process or technology would be run side by side, all other things being equal, and the outcomes and costs compared.

Unfortunately, classroom research in the military has had limited usefulness for training cost effectiveness, particularily for new computer-based technology, because of large front end costs for software development and hardware procurement, the expense and disruption of sufficiently large controlled experiments, and because current test measures typically show high average levels of classroom achievement (i.e., ceiling effects). At the same time, these test data are generally not validated by subsequent performance at duty stations in the field. The expense and disruption of experimental research limits the number of experiments. Ceiling effects and the unproven reliability of outcome measures make it difficult to justify the costs of new technology on the basis of improved training.

There is, however, one important new technology that has had less difficulty proving its worth : computer-based equipment simulation (Orlansky & String, 1977, 1981; Orlansky, Knapp, & String, 1984; Fletcher & Orlansky, 1985). Many flight and maintenance simulators pay off in the economic sense that dollar measures of benefit exceed cost. Such analysis can be done in these exceptional training circumstances if simulation constitutes a clearly differentiated training activity, and if simulation outcomes can be defined in terms of time necessary to complete training using actual equipment. In that case, costs can be quantitatively compared to effects in terms of "transfer-effectiveness ratios". Furthermore, experimental research to optimize simulation use can be gracefully incorporated into existing instructional process in terms of marginal adjustments in the amount of time students spend on simulators or marginal changes in simulation technology.

It is the working hypothesis of this Report that automation of classroom training can extend the domain for CTEA analysis in a way similar to equipment simulation. It does so by helping to differentiate training activities into technically and economically distinct subprocesses. Automated activities are separately programed; computer equipment is separately budgeted; and, in order to evaluate new applications, the mix of instructor- and computer-initiated activities can be adjusted along existing seams that normally connect different classroom activities. These changes wrought by computers invite quantitative analysis and cost effectiveness tradeoffs.

However, compared to the equipment simulators mentioned above, classroom computers are much less self contained. Their instructional value derives much more from functional integration with all other forms of classroom instruction. This complexity, coupled with the apparent success of current instruction, make it difficult to justify automation on the basis of greater effectiveness. With the exception of job task simulation (See policy section below), the cost effectiveness of classroom automation is most likely based on cost savings.

Furthermore, automation is more likely to prove cost effective as a series of marginal increments, each one integrated into classroom process before attempting the next, because large changes can easily prove too disruptive and too difficult for existing outcome measures to evaluate. These practical considerations are reinforced by methodology and policy described below. The next Section of this Report describes current classroom training as a productive process, where margins for cost saving automation can be identified, if they exist.

CLASSROOM TRAINING AS PRODUCTION PROCESS

The 76C10 Course (and many other AIT courses in the Army) is divided into annexes, and each annex is broken down into separate blocks of instruction. Instruction blocks vary in length, but the pattern of activity in each is roughly the same.[3] First comes platform lecture, for a prescribed period of time, in order to present new material and to answer questions from the entire class. Averaged over the entire Course, about 50% of class time is prescribed for platform presentation, although not all of this time is actually devoted to technical training (Figure 1). Frequently, instructors interrupt technical training in order indoctrinate or "soldierize" trainees, who by and large are relatively new to Army organization and discipline. In fact, the dual role of platform instructors, as authorities in both job skills and other military doctrine, restricts opportunities for classroom automation because computers are much less effective for indoctrination.

Following lecture, all soldiers receive a printed set of instructions and questions as a practical exercise (PE). Since PE scores are generally not recorded, this is mainly a time for soldiers to check themselves and to seek more personal attention from instructors, if needed. Instructors may also monitor student performance at this time in order to select slower students to attend study hall after normal classroom hours. PEs take up about 40% of class time.

Test and evaluation of soldier knowledge and skills occurs at the end of an instructional annex. An annex is made up from 5-17 blocks. For students who fail the initial end-of-annex test, remedial training is required during off-hours, and then they are immediately retested. Failure to pass a second time results in recycling back to take the annex over again. (Repeated recycling results in being dropped from the course.) Testing and related reviews and critiques take up about 10% of class time.

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3. All instruction in this Course pertains to prescribed procedures for taking inventory, filling out request and file forms, using appropriate manuals as references, and filing documents properly.

In the official Program of Instruction (POI) (1987), this entire instructional sequence is defined or denominated in terms of instructor contact hours (ICH). Each stage of the process shall consist of a certain number of ICH. The entire Course requires 360 ICH. Because there are only 36 classroom hours in a 5-day training week, the 360 ICH requirement translates into a 10-11 week residence time at Fort Lee for trainees (allowance must be made for programmed days off plus holidays).

During the two main instructional activities (lecture and PE), it is expected that most learning will take place under the direction of instructors. All soldier trainees are supposed to learn at the same time, in "lock-step", following directions from the platform. Instructors provide personal attention to individual students, but their limited training in instructional methods and the procedural nature of the subject tend to restrict instructional process to repetitive presentation of the same material, followed by drill and practice routines. Furthermore, peer interactions among students in the classroom is generally discouraged (with the exception of cooperative learning, see below), and few opportunities exist for student initiative.

Figure 1

The Organization of Instructor Contact Hours (ICH)
During a Generic Instruction Block

50% 40% 10%

Lecture Practical Exercise (PE) Testing

Source: 76C10 Master Scheduling Form, Fall, 1986.

This brief overview of 76C10 training process sets the stage for a quantitative analysis of its cost and effectiveness. With training as currently organized into a "lockstep" procedure, the notion of training time as cost driver can be further explicated in terms of instructor contact hours (ICH). How does instructor contact with a class constitute a flow of costly inputs that may be charged to 76C10 training? On the other hand, how does instructor contact generate a flow of training effects or products that justify the cost of expensive inputs?

Both questions are addressed below in terms of cost and product curves that describe cost and product flows, hour by hour. These "marginal" and "average" curves are basic in the economic theory of production. Economics is a science for making comparisons among alternative options and outcomes; and these economic curves will be used to suggest how adjustments in the training schedule and perhaps investment computer-based instruction may increase productivity per unit time and thus payoff in terms of reduced total training time.

Costs will be discussed first, as a function of the flow of ICH, because this relationship involves only straightforward accounting, using data already collected for administrative purposes. Productivity curves, considered second, require closer examination of how or when instruction results in learning. In both cases, however, notice that the analysis pertains first to a class of 40 students. Classroom data are then used to compute cost per student. Also notice, for both cost and productivity analysis, instruction time (as calibrated into ICH) serves as the critical explanatory variable.

Classroom Cost

The following cost analysis takes advantage of the fact that in lock-step training, the causal relationship between the flow of training inputs and the flow of outputs goes in only one direction. With the minor exception of study halls, the flow of costly inputs does not vary as a function of when learning takes place. This simplification makes it possible in the first instance to consider costs independently of effects or productivity.[4] Later on, costs and product will be combined as they must in order to evaluate cost effectiveness.

Furthermore, lock-step training policy makes it unnecessary to differentiate among the cost components (see Table 1 and related discussion), because the input mix does not change during the course of instruction. All soldiers remain in the classroom, along with 2-3 instructors, at all times (or at least without regard to the schedule of instructional activities). In other words, instructor contact hours (ICH) is a convenient surrogate for all factor inputs.

During a block of instruction, the same training cost is incurred, hour by hour, because the process involves a constant set of costly inputs. As shown by the lower line in Figure 2, marginal cost (MC) per hour of instruction can be illustrated as a straight, flat line. Notice that the horizontal axis is a slight truncation of the ICH scale presented in Figure 1 (testing is omitted). The vertical scale represents dollars. Since it costs approximately $300k to train a class of 40 soldiers for 360 ICH, the marginal cost per ICH equals about $830. This might simply be called the cost per ICH, because it does not vary over time within an instruction block or among instruction blocks, but a marginal aspect still exists in the sense that training inputs and thus costs could differ during different parts of the Course depending upon the instructional goal and the subject matter (See below). At the moment, however, constant costs per ICH are the rule.

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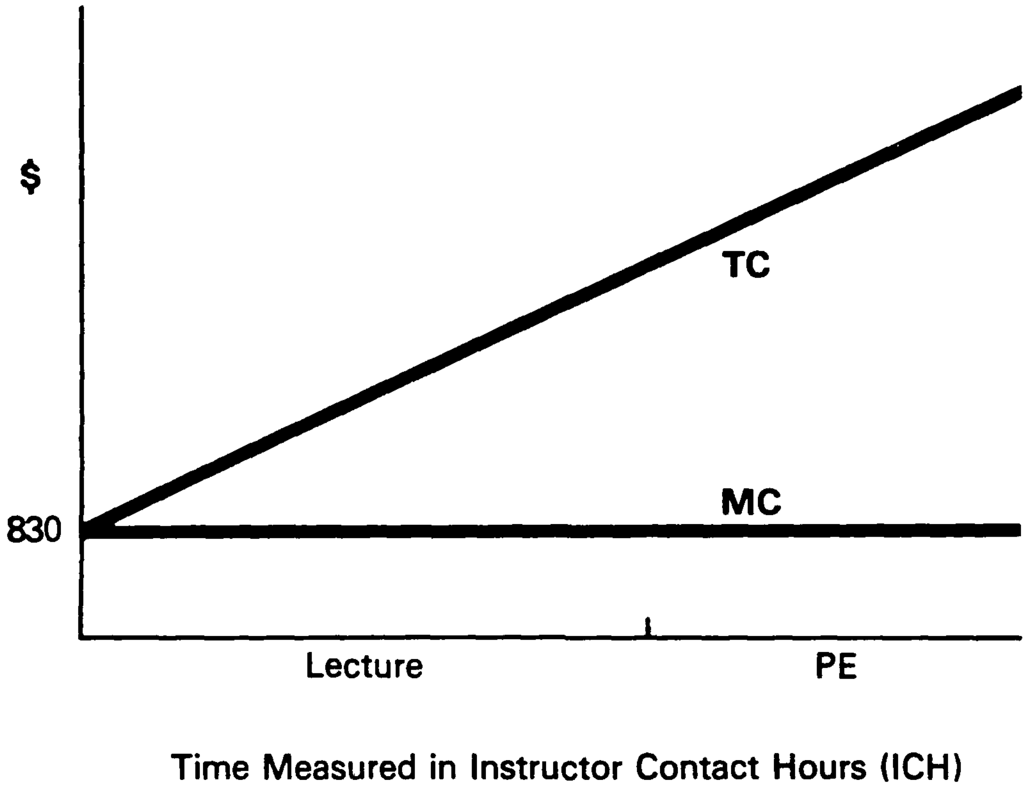
4. Costs would not be independent of effects if training were self-paced as it was prior to 1983. In that earlier training program, improved instruction lowered costs directly by shortening training time. In lockstep training, the interplay between cost and effectiveness involves indirect, administrative actions.

Figure 2
Costs Over Time During a Generic Instruction Block



The upper line in Figure 2 illustrates total training costs per instruction block. Total cost equals the sum of marginal costs or the area under the marginal cost curve. The level of marginal cost curve is the slope of the total cost curve. Note that total costs are left indefinite since they depend upon the variable number of hours allocated to each block.

However, the level marginal cost curve permits calculation of cost savings that may obtain from shortening training time. One instructor contact hour (ICH) costs $830, and if 95% of these costs could be saved by shortening training time, then an hour reduction for one class saves $790. Over a year, an hour reduction for 75 classes would save $59,000. Saving a day of instruction (7.2 hours), for all classes trained for one year, would save almost $425,000 in annual training costs. Actual cost savings would require more detailed cost accounting, but this ballpark estimate will be used later on to explain how investment in computer software may leverage offsetting cost savings by shortening the length of training. The following discussion of training productivity is designed to identify when time savings are most easily achieved during the course of training.

<u>Classroom Productivity</u>

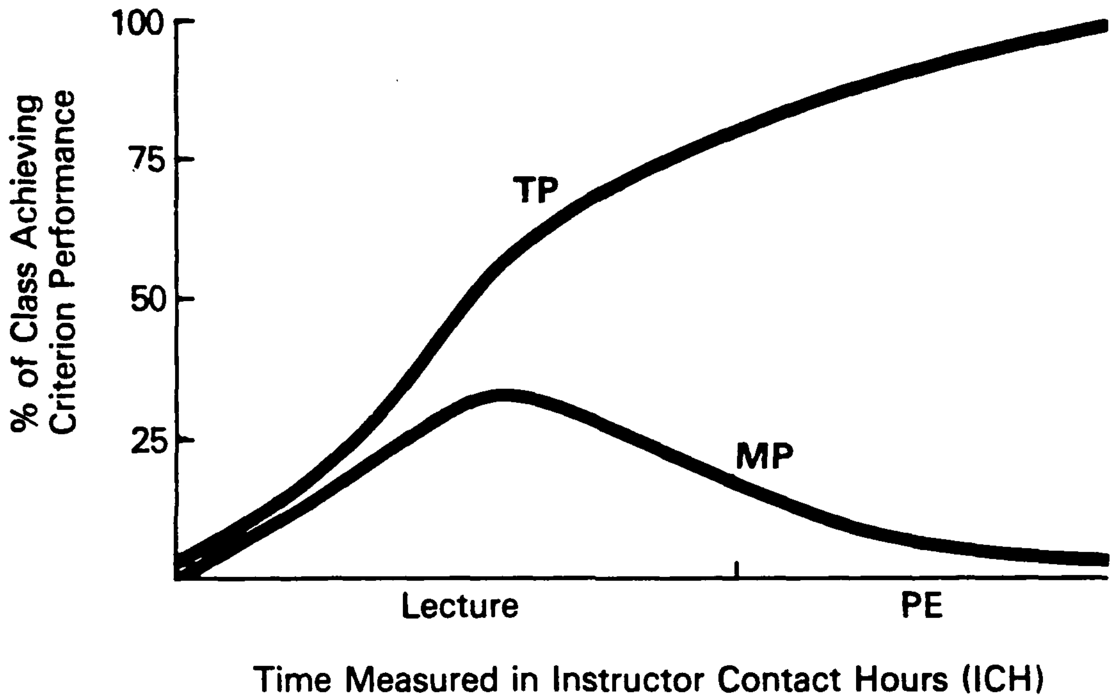
Total output from the Course can be measured in annual terms comparable to annual cost data. About 3000 76C10 soldiers graduated in FY 1987. This total can also be disaggregated into shorter time intervals, but unlike marginal costs, there is no accounting procedure to derive marginal (hour by hour) classroom productivity. While policy and established administrative procedures can prescribe the incidence of training costs, they can not prescribe when students learn the required material. In order to develop a marginal productivity curve, the product of training must first be defined in practical terms that permit students to demonstrate knowledge and skill.

Productivity in the 76C10 Course is measured almost entirely by objective tests, administered at the end of each annex as well as at the end of the entire course. The success criterion is a single cut score (e.g. 85%) and little benefit accrues to either the school, the instructor, or the student for test scores that exceed this threshold. A similar performance criterion is used at many Army schools for advanced individual training (AIT) (perhaps because they all share the same difficulty in trying to validate test instruments against performance in the field).

Accepting this pragmatic performance criterion, marginal classroom productivity may be defined as the number of soldiers meeting the test criterion, <u>hour by hour during an instruction block</u>. Figure 3 illustrates such a curve as a relationship, driven in real time, by instructor contact hours (ICH). The lower curve (with the inverted "U" shape) is the marginal product (MP) curve. The upper curve (with approximate "S" shape) is the total product (TP) curve or the cumulative sum of soldiers meeting criterion (i.e. the area under the MP curve).

Figure 3

Productivity Over Time During a Generic Instruction Block
(Illustrative Hypothetical Data)



Unfortunately, since existing tests are administered only at the end of each annex and at the end of the course, existing test data do not permit estimation of hour by hour or even block-specific productivity curves. Formal estimation of the latter would involve sampling out of the class, during the course of instruction. More informal estimation procedures could also be used, such as self evaluation by students based upon when they can correctly answer test questions that would be passed out at the beginning of instruction. The objective of this analysis is to show why such data gathering, by whatever means, may be worth the effort. Prior to collection of data, but based upon extensive classroom observations, the curves in Figure 3 illustrate a plausible hypothesis about productivity in the 76C10 Course.

Since classroom marginal productivity is not a familiar notion, the basic concept may be explained first by an analogy to popping popcorn over a constant heat source. Heat is applied and at first nothing happens. Then one kernel pops; then another and another as the rate increases until most kernels pop in a flurry. Then the popping tapers off, showly, until only a few unpopped kernels remain. Current testing in 76C10 Course, at the end of each annex, is analogous to measuring the total number of popped kernels emptied from the container after removing it from the heat.

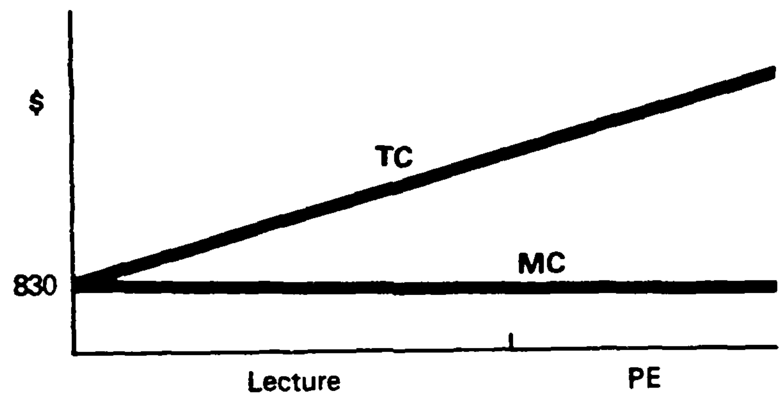
The marginal productivity curve (Figure 3) shows when individual students "pop above" the performance criterion. However, before examining the shape of this curve for 76C10 training, it should be noted that productivity could be measured in different ways, with different curves resulting. For example, in making popcorn, the popping process might have been more sensitively monitored in terms of the number of kernels heating up times the average rate at which they heat up. Presumeably, this curve would start out on a peak or high plateau, when all kernels would start to warm up from room temperature, and then taper off first because the heat rate falls as the kernels' temperature rises and then because, as kernels pop, fewer kernels would be left to heat. Although the rigorous case has not been made, it should be clear that this more sensitive measure of productivity would show more production during the early phase of popping, compared to simply measuring when kernels pop.

A more sensitive measure of productivity in training might be considered if rate of learning could be estimated. However, the latter is much more difficult to define than in the simple case of popcorn, and certainly more expensive to measure than simply noting when students "pop above" the performance criterion. Furthermore, the same argument can be made (as in the case of popcorn) that the more sensitive measure would show greater production during the early phase of training, and less production later on. Since the difference between learning, early and late, lies at the crux of the argument presented below, the use of the less sensitive measure of productivity implies that a better measure would only reinforce the conclusions.

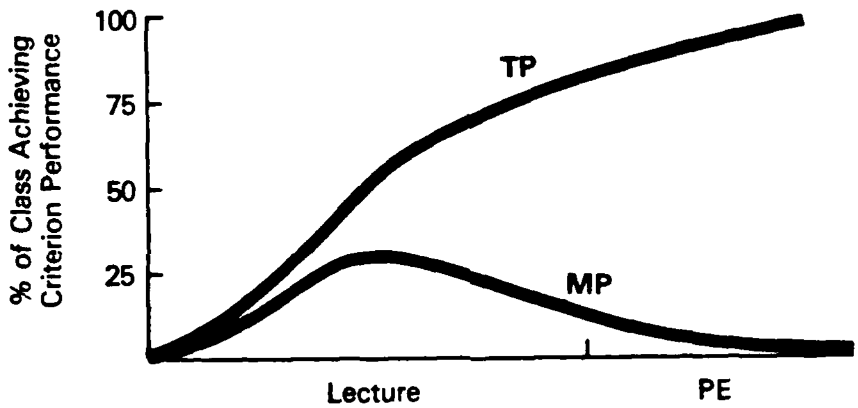
Figure 4

Costs Per 76C10 Student
(Illustrative Hypothetical Data)

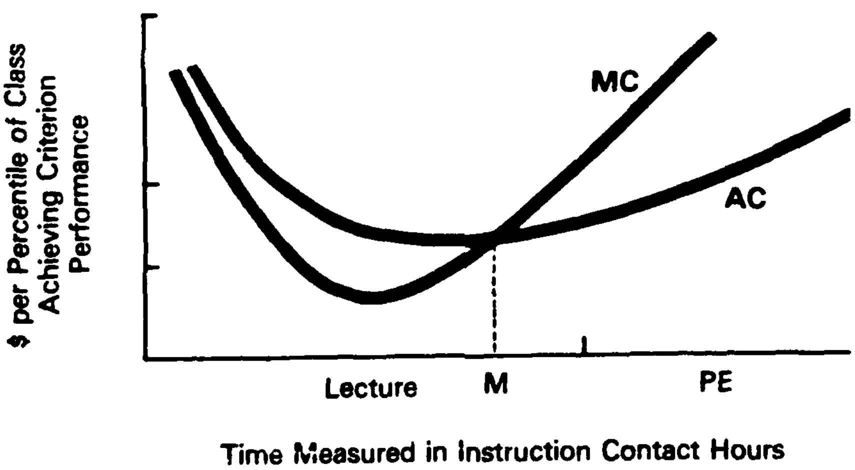
a. Classroom Costs



b. Classroom Productivity



c. Costs per 76C10 Student



Assuming the performance criterion measure as it is used in the 76C10 classroom, the approximate position and shape of the marginal product and total product curves can be postulated on the basis of the instructional process and the mix of soldiers in the classroom. Soon after instruction begins, this curve can be expected to rise from zero, gradually at first and then more and more rapidly until the lecturer has explained all new procedures. The initial rise reflects the fact that some students have previous experience with the material, or are exceptionally adept or self-motivated, and thus will more or less teach themselves quickly, if necessary using directions contained in printed manuals.

Most trainees, however, will wait for the instructor to cover the required material because there is little institutionalized incentive to get ahead or to seek understanding of details greater than is required by the instructor. Immediately after all new material has been presented, perhaps 50% of the class can meet the proficiency criterion. As the lecture continues on, fewer and fewer new students meet criterion, because a majority of students already have done so, because further instruction is generally limited to repeated review of procedural details (i.e. not tailored to slower students), and because of the large apparent variability in aptitude or motivation (despite pre-screening) among those who learn slowly. Since the course length appears to be determined by the requirements of slower students, the marginal productivity curve can be expected to have a relatively long right tail, running near the horizontal axis.

Based upon extensive classroom observations, the MP curve in Figure 3 also illustrates a plausible range of variation between the "modal" or peak number of students (25% of the class) who reach criterion just after the initial presentation of new material, and the low number (5%) reaching criterion near the end of the right tail of the curve. In the following analysis, the shape of the marginal productivity curve and the pattern of shapes among instruction blocks determine opportunities to improve training cost effectiveness.

Marginal Cost per Student

These two pairs of curves that describe a classroom of students, one for cost and the other for product, can now be combined to calculate training costs per student, as a function of instructor contact. Cost per graduate can be obtained by aggregating or adding costs across all instruction blocks and annexes. For simplicity, however, we will continue to consider only one instruction block, assuming it is representative of the entire course. If this were true, then the variability in average and marginal costs within this representative instruction block would reflect such variation over the entire Course. On the other hand, differences among instruction blocks will prove critical in targeting the application of computer technology.

The three frames in Figure 4 illustrate the mathematics involved. All three frames line up along the same horizontal axis. The top two frames [a & b] merely reproduce Figures 2 and 3 respectively. The bottom frame [c] takes the ratio of cost per class from [a] and product per class from [b] to obtain cost per percentile of the class. The latter can easily be converted to cost per student. The marginal cost per percentile or per student (i.e., the more irregular, "u" shaped curve) equals classroom marginal cost divided by classroom marginal product. The average cost per student equals classroom total cost divided by classroom total product. Notice that the marginal cost curve intersects the average cost curve at its minimum point (marked "M").

Both the average and marginal cost curves, if aggregated across all blocks and annexes in the Course, invite comparison to the single average cost per soldier for the entire Course (Table 1). However, the marginal cost curve highlights the effective range of cost variation among individual soldiers. If the peak of the marginal classroom productivity curve accounts for 10 soldiers (25% of the class of 40 students), and the low point on the right tail accounts for only 2 students (5%), then training cost per soldier in the small group is 5 times greater than for each soldier in the large group. Without actual data for classroom productivity, this difference remains hypothetical, but large differences are at least possible, if not probable. In any case, for Course managers and higher level administrators, this description of costs as a curve, instead of a single number, helps to identify cost effectiveness tradeoffs.

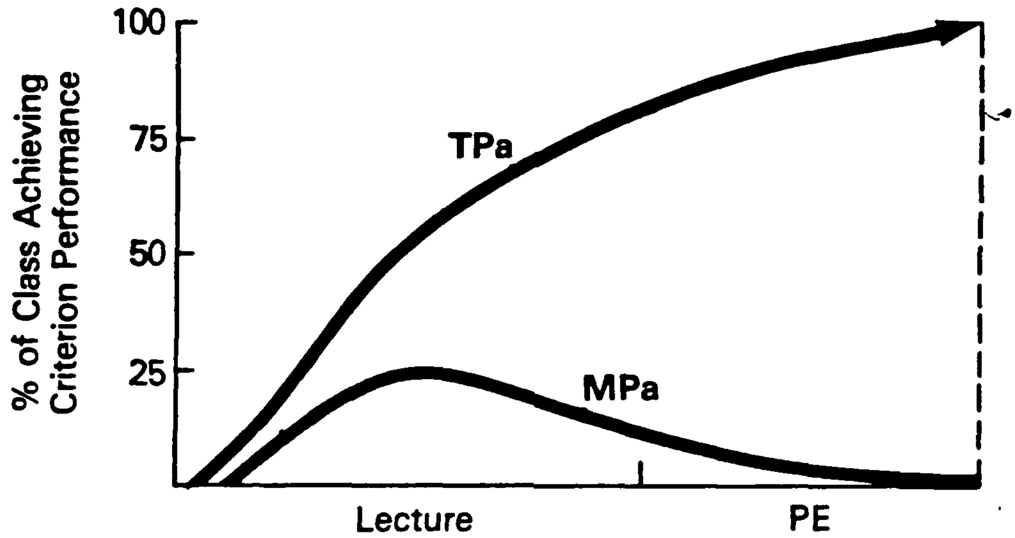
A basic tradeoff compares cost savings from shortening programmed training time to cost increments that may result if shortened programs result in more recycles. Shortening programmed training time reduces costs for all soldiers reaching criterion within the shorter period, but it increases training costs for those who must repeat failed annexes. Note that actual Course length (or required training time averaged over all graduates) exceeds programmed Course length by an additive factor that is proportional to the number of recycles. With actual productivity data, the tradeoff could be systematic.

Expected variation in marginal productivity, among blocks, implies that programmed training time can be shortened more easily in certain blocks than in others. Figure 5 illustrates two extreme cases for classroom marginal productivity. Frame [a] shows a relatively large window of opportunity to reduce costs by shortening the Course. This MP curve has a short upward sweep and a right tail that is long and low. Reducing classroom hours here would adversely affect fewer soldiers than in Frame [b], where the MP curve has a long upward sweep and a short, steeply sloped right tail. If actual classroom productivity data were collected, then an obvious way to reduce training time at <u>zero net cost</u> would be to adjust programmed training time in all instructional blocks so that an hour time reduction, allocated to any block, would have the same net effect on cost due to increased recycles.

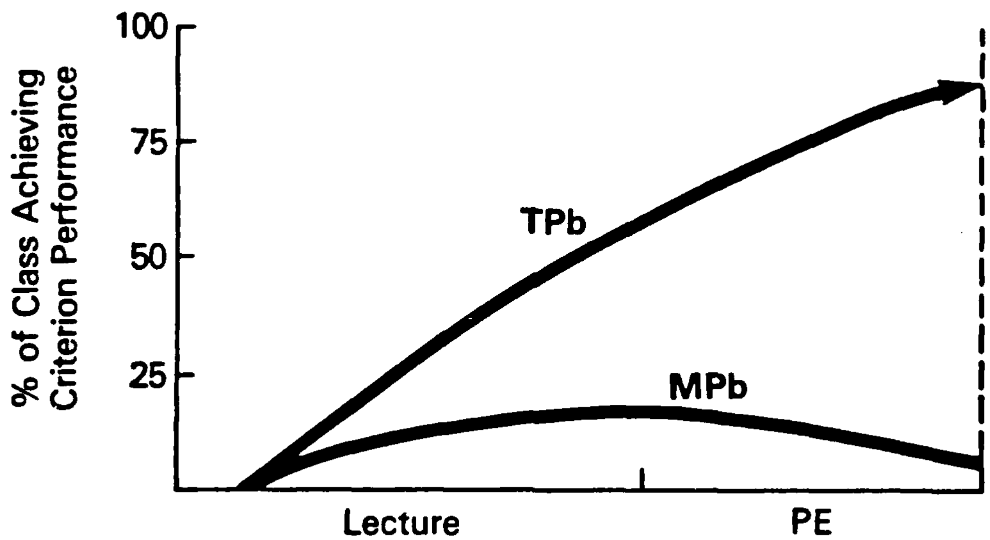
Figure 5

Larger and Smaller Windows of Opportunity to Improve Cost Effectiveness (Illustrative Hypothetical Data)

a. Larger Window



b. Smaller Window



Similarly, the instructional block described in Frame [a] offers greater opportunity to shorten the course by upgrading instruction. Along the long, low right tail of the MP curve, most soldiers have already mastered the required skills and only a few have not. As discussed further below, this is a likely situation to engage the larger group on computers so that instructors can focus greater attention on the smaller group. Frame [a] offers greater opportunity to shorten the course than Frame [b] because there are fewer slower learners to speed up, per hour saved.

Average training time may be shortened by a variety of other measures, such as allowing soldiers to move ahead once they have met criterion performance, or engaging faster students to assist the others (See discussion of cooperative learning below). However, the main purpose here is to consider automation options. Computers can be used in different ways to train, and some options save time and some do not.[5] One option, automation of hands-on practical exercises, has already been implemented in a 3-week extension of the basic 76C10 Course (See TACCS/SAMS below), and the same option has been approved for implementation in 76C10 during the next fiscal year. A review of current automation policy at this point will help to determine which cost and productivity data and which automation options are policy relevant.[6]

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5. For a review of cost effectiveness data for computer-based instruction, as a substitute for conventional classroom training, see Orlansky and String (1979). These data were collected prior to the advent of inexpensive microcomputers, but favorable implications for the cost effectiveness of individualized instruction are only reinforced by recent technological developments.
6. For an early discussion of the need to define automation options realistically, see Seidel and Kopstein (1970).

CURRENT SCHOOL POLICY FOR CLASSROOM AUTOMATION

The Hands-On Training Requirement

The 76C10 Course is not automated, but there is little doubt that it will be. Not automating is not an option. Computers will be used in the classroom because they are or soon will be used as tools on the job. Computers will be used to simulate automated job tasks because "hands-on" the actual equipment is the best way to train inside or outside of classrooms.[7] The Department of the Army supports this policy by supplying automated workstations to the Quartermaster School, at no charge, just as it supplies workstations to operational units.

This automation requirement is policy background for all questions about the cost effectiveness of CBT. The issue is not whether 76C10 will be automated, but how the necessary introduction of computers into classrooms should be managed. Alternatively, the issue is not whether automation is cost effective; but only how to make it as cost effective as possible.[8]

The first hands-on automation planned for 76C10 involves the Unit Level Computer (ULC) and the Unit Level Logistics System (ULLS). Training on both is currently planned to extend the Course by 65 hours or about 9 days (a 17% increase). The ULC computer is a stand alone, general purpose microcomputer that according to design specifications will have systems software amenable to training as well as to field operations. (Actual equipment has not yet been procured by the Army.) The Supply Department at the Quartermaster School is scheduled to receive 176 ULC machines during the third quarter of FY88. 132 machines will be used to equip 3 classrooms, the number necessary to cover a two week interval, since 2 classes of up to 44 students start training every other week, with one class starting during the week in-between. Training on the ULC/ULLS system is planned to begin during the first or second quarter of FY89.[9]

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7. This conclusion is based upon extensive conversations with instructors and managers in the 76C10 course, with course developers and managers within the Supply Department and the Directorate of Training Development (DOTD), and it is based upon the 1987 QMS Individual Training Plan for 76C10. Furthermore, discusssion at the 1987 National Security and Industrial Association Workshop on Manpower and Training indicated that hands-on training is of highest priority for advanced individual training (AIT) at many Army schools and in the other Services as well.

8. It is expected that some EIDS (Electronic Information Delivery System) workstations will also be available for use in 76C10. However current plans would employ this equipment only for ongoing research into computer-based instruction.

9. Procurement and implementation plans for ULC/ULLS obtained from Mr. Lew Thayer, Branch Chief in charge of 76C10 training at the QMS.

Many details related to the plan of instruction and costs have yet to be worked out, but discussion with Course managers indicates that implementation will generally follow the precedent established by a current extension of the basic 76C10 Course, the 3-week Course designed to teach the Tactical Army Combat Support Computer System/Standard Army Maintenance System or TACCS/SAMS.

Computer Use in the TACCS/SAMS Extension

Automation policy at the Quartermaster School has been demonstrated already in terms of an extension of training for a subset of 76C10 graduates. For about two years, the Supply Department at Fort Lee has held over about 10% of 76C10 graduates for 3 weeks in order to train them on TACCS/SAMS (Tactical Army Combat Support Computer System/Standard Army Maintenance System). While most 76C10 graduates work at the lower "Unit" level, TACCS/SAMS is used at the higher organizational level of "Direct Support" (DS). TACCS/SAMS is a new automated system for DS operations. Because the basic 76C10 training deals only with manual DS procedures, TACCS/SAMS requires a 3-week extension of the basic course.

In this first application, the only purpose for computers is to give students initial hands-on simulation of automated job tasks that is as realistic as possible. Computer use is limited entirely to practical exercises where the nature of automated training is predetermined by computer use on the job. Other than the substitution of computers for paper and pencil during these practical exercises, the basic instructional design remains unchanged. Soldiers follow the platform instructor in lock-step, during the presentation of all new material. Hence, there is little need for course developers to consider the instructional capabilities of these machines beyond what would be done by subject matter experts, in their usual roles as course developers and instructors.

Nevertheless, this introduction of computers into the classroom involves costs. The Training Cost Breakdown Structure (TCBS) (Seidel and Wagner, 1977) has been designed to examine costs when new automation technology is introduced into a training system. While the Cost Element Structure (CES) (Knapp and Orlansky, 1983) could be used for this purpose, its fidelity to military budgeting is less important than the functional classification scheme used in TCBS. For example, CES repeatedly distinguishes between military and non-military personnel costs while TCBS makes no such distinction at all. If the QMS were contemplating automation as a major overhaul of 76C10, then it would be more appropriate to use military accounting conventions. But as long as the focus is primarily on complements to the present lockstep system (based upon instructor initiative), and as long as experience with classroom automation remains limited, the TCBS identification of costs of computer based training (CBT) by system component (e.g., terminals, utility programs, and memory) involves fewer assumptions.

Furthermore, TCBS is a more workable accounting system for planning purposes since costs of automation are changing rapidly, driven by industry-wide trends in technology that are specific to CBT components. Even after component technology and costs settle down, it takes time for course administrators and cost accountants to fit the relatively new training costs (e.g., new classrooms designed for computer workstations, machine maintenance) into existing programs and budgets. Hence, even though TACCS machines have been used in a classroom for about a year, their impact on CES-type administrative budgets remains less clear than in technologically specific TCBS accounts.

Table 2 employs TCBS accounting to describe automation costs for the hands-on PE segment of TACCS/SAMS training. Note that certain CES accounting items, such as AIT soldier pay and allowances or "base ops," are excluded because they would not be affected by use of computers for hands-on practical exercises. Of course, the basic rationale for this Course extension is the need to teach soldiers how to use an automated system in the field, and in that sense all training costs could be considered "automation costs." But our concern here is only to evaluate training costs and effects with and without computers in the classroom. Presumably, soldiers could be trained on TACCS/SAMS without actually touching a computer, just as the present 76C10 Course trains automated prescribed load list (PLL) procedures using pencil and paper.

Table 2 shows that TACCS/SAMS hands-on automation involved no QMS investment for the development and procurement of operating workstations. Hardware costs the School nothing because the QMS received computers as part of the Army-wide procurement that placed TACCS machines in direct support (DS) units in the field. Similarly for computer systems software, because the QMS does not use their TACCS machines for any other instructional purpose than simply emulating field operations. Finally, no costs were incurred specifically to develop a new instructional system since the TACCS/SAMS Course extension conforms to the 76C10 mold. In summary, the QMS automated this first segment of 76C10 with minimal front end investment that could be charged specifically to the automation of training.

Of course, new instructional materials were developed (line 5), but this was done over a short period of 6 months and a similar investment would have been required to teach this new course, with or without automated hands-on. Similarly, new facilities would have to be built or found, with or without. However, automation added significant new facilitites costs as it increased requirements for space, space conditioning, furniture, and electrical utilities.

Table 2

Computer-Related Outlays and Costs for TACCS/SAMS Extension of 76C10

1.	Hardware*	$0 (QMS)** $220,000 (Dept. of Army)
	(11 TACCS-V2 workstations at $20k per, 1984 procurement plus upgrades)	
2.	Facilities*	$72,000 (QMS)
	(one classroom renovated plus new furniture)	
3.	Computer systems software*	$0 (QMS) $? (Dept of Army)
4.	Instructional system development and instructor preparation	$0
5.	Instructional materials*	$58,000 (QMS)
6.	Operation and maintenance	
	consumables	$600/yr/machine or $6600/yr total
	machine maintenance	$1400/machine/yr or 15,400/yr total
	instructor pay and allowances [(1) E7 and (3) E6's]	$125.500/year

Source: Supply Department at the Quartermaster School, Fort Lee, VA.

* Initial Invest outlays, not annual costs

** Parentheses adjacent to cost estimate indicates who pays.

Note: Although TCBS accounting partitions costs into 3 phases of an automated system's lifecycle, all 3 phases (development, procurement, and operation/maintenance) can be folded together when computers are used only to automate practical exercises. See following text for further explanation how the front end of the technology lifecycle is shortened in practice.

Two new costs are incurred under the heading of operation and maintenance: computer consumables and machine maintenance. These two items amount to a little less than $25 per week per soldier, which is a little more than 3% of the weekly cost for training a 76C10 soldier. This might be considered a small but significant cost increment if a similar hands-on system were implemented in the basic course. Notice that costs are computed per week in order to permit cost comparisons between courses of different length.

Instructor pay and allowances require a bit more effort to evaluate. The salient question concerns the ratio of instructors to students --- does the introduction of automated hands-on increase or decrease instructor requirements? Again the comparison is to the basic 76C10 course, where between 65-83 instructors teach a 10 week course to approximately 3000 soldiers each year. That puts about 600 trainees in classes at one time, for a student/instructor ratio between 7-9. In TACCS/SAMS, 4 instructors teach a 3-week course to about 300 soldiers each year. Thus, about 18 trainees are in classes at one time, for a student/instructor ratio of 4.5. In other words, automated hands-on appears to increase instructor requirments. The additional cost per student per week amounts to about $50, or about 7% of the weekly training cost in 76C10.

Comments from supply department staff suggest one reason why greater classroom supervision may be needed. For hands-on practice, soldiers are required to assemble and disassemble workstations as they would do in the field. Since the equipment is expensive and somewhat fragile, additional instructors are needed to reduce breakage. Although this added instructor input may indeed be justified in order to effectively train automated job tasks, it is nonetheless somewhat ironic that computers, with their generally acknowledged instructional potential, should increase rather than decrease requirements for human instructors. It should also be noted that the extension of training time needed to teach new automated job skills increases training costs by much more than added instructor input. Mainly because of this extension of training time, this first introduction of computers into the 76C10 classroom substantially increased training costs without upgrading existing instructional process in terms of more efficient use of time.

COST-EFFECTIVE CLASSROOM AUTOMATION

Future options for classroom automation and ways to evaluate their cost effectiveness can now be considered within the relevant policy context. The latter includes not only current automation policy but also broader fiscal considerations that motivate interest in cost effectiveness in the first place.

Incremental Add-Ons to Hands-On Software

Current policy for classroom automation at the QMS, and at other Army Schools, makes cost effectiveness analysis unnecessary for basic investments in computer equipment and appropriate classroom facilities. These investments will be made and used to automate practical exercises when job tasks are automated in the field. While this policy ignores other instructional uses for these computers, it nevertheless makes additional uses less costly since at least the compatible hardware is in place already, and not used during much of the training process. Consequently, additional instructional uses for these computers need incur only incremental software costs.

On the other hand, by limiting classroom automation to hands-on simulation of job tasks, the Quartermaster School and other Army schools affirm the primary instructional value of lock-step contact between an entire class and the platform instructor. In the same way, this limited used of expensive equipment implies doubt about more advanced or extensive instructional applications of computers, or at least an unwillingness to pay the associated front end investment costs.

Taken together, the existence of hands-on workstations and the implied skepticism about computer-based instruction suggest that classroom automation beyond hands-on simulation is most likely to prove cost effective in small increments. These might be called "add-ons to hands-on training". Because they would capitalize on hardware and software investments already made, and on the growing experience of using computers as adjuncts to existing platform instruction, "add-ons" would cost less than "stand alone" options, and their modest instructional objectives could be demonstrated via relatively small perturbations in existing instructional process.

Add-ons to hands-on software might start with additional practical exercises, similar to those already programmed by subject matter experts for hands-on simulation, but some exercises could be easier and some harder in order to expand the amount of time that slower and faster students could learn at the computer. Add-ons could also involve more elaborate programming of exercises, increasing their instructional value, perhaps via error analysis, more timely review of instructional material, or more subtle adaptation of problems to the skill level of the trainee. For the soldiers who can use them, such changes reduce the need for instructor supervision, thus giving instructors more time with those who need human help the most.

Needless to say, these add-ons will still require investment dollars as well as adjustments in current classroom procedures, albeit marginal amounts of both. The cost effectiveness methodology proposed above is designed to identify instructional blocks where such marginal changes may have the greatest impact on training time and thus on total training cost. However, before discussing methodology further, attention to cost effectiveness tradeoffs may be motivated by relating current automation policy to the recent tightening of training budgets.

Current automation policy and recent classroom experience with computers, as far as they go, increase training cost. Although the preceding cost analysis showed higher cost per unit of training time, cost increases occur mainly because the Course has been (e.g., TACCS/SAMS) and will be (e.g., ULC/ULLS) extended in order to teach new automated job tasks. Training improvements that have or will result from automated hands-on may indeed outweigh their costs, but in an era of tightening budgets, any added cost increases fiscal pressures to cut costs elsewhere, or to lower training standards. In fact, in FY88, costs for the 76C10 Course are being cut by reducing the number of instructors and course development staff by up to 50%.[10]

Such cost cutting contrasts with the strategy proposed at the beginning of this report (See Cost Driver and Leverage, above). According to that cost analysis, the most powerful cost cutting strategy would shorten the length of training because Course length drives over 95% of training costs. In fact, cutting back inputs to technical instruction may increase actual (average) training time, and thus defeat the larger cost cutting objective. In other words, cutting back on technical instruction may run the leverage argument in reverse. Since inputs to technical instruction account for a relatively small share (14%) of total training costs, a large percentage cut here accounts for a much smaller percentage reduction in total costs. At the same time, <u>as long as training standards are maintained, a large cutback in instructional resources may slow down the training process, increasing actual training time, and on balance causing an increase in total training cost</u>.

<u>Tailoring Instruction to the Subject Matter and to the Student</u>

An alternative approach to cost reduction would target hands-on add-ons to blocks of instruction that offer the most attractive opportunities to shorten training time. As discussed above, these blocks would have a marginal productivity curves with right tails that are relatively long and low. To continue the comparison between the two instruction blocks illustrated in Figure 5, assume that the right tail of marginal productivity in block [a] runs around 1-2% of the class during the last several hours of instruction, while the right tail in block [b] runs around 8-10%. Block [a] offers the more attractive opportunity for hands-on add-on software because any increase in the rate at which soldiers meet the criterion will permit a larger reduction in training time, while holding the number of recycles constant. For example, if the slowest soldier achieved criterion one hour earlier in both blocks, as a result of greater attention from the instructor, that would <u>not</u> permit shortening block [b] but it would justify chopping one hour off of block [a].

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10. Personal communication with Lew Thayer, Branch Chief in charge of 76C10 training.

Furthermore, this targeting of hands-on add-ons enables instructional inputs to exercise maximum economic leverage over training costs. By reducing actual training time by a day, for all classes during one year, total training costs can be reduced by about $425,000 (see calculation above). If this were accomplished by add-on software, and if the latter had a useful lifetime of 3 years, then this annual savings could amortize over a million dollar investment. Given the minimal training objective --- to engage the bulk of students in activities not much different than what they would already have done to simulate automated job tasks --- such an outlay would seem large. But even if a million dollars were invested, its cost saving leverage would also be great. A million dollar investment would increase total annual training costs by less than 5%, and 3-year total training costs by proportionally less, while it increases annual inputs to direct instruction by about 33%. It would seem likely that such an investment in instructional software could account for more than a 2% reduction in current training time (one day out of 52 days).

The main methodological point is that such targeting of add-on technology, to instruction blocks where it can have the greatest impact on training time and cost, provides an economic rationale for tailoring instruction and instructional technology to the subject matter being trained. Furthermore, if different rates of learning reflect different instructional needs, then this approach to cost effectiveness also suggests an economic rationale for tailoring instruction more to the needs of individual students.

There is a recent example of a change in the Course, involving cooperative learning, that indicates a willingness by Course management and staff to take advantage of individual differences in order to improve training and reduce costs. The Training Technology Field Activity Program (TTFA) at the Quartermaster School examined the effectiveness of cooperative learning during practical exercises in the 76C10 Course. Cooperation within four-person groups reduces instructor burden by enlisting faster or more motivated students to answer questions of slower students or to motivate the less motivated. As discussed in Brooks et al. (1987), recent ARI research shows that cooperative learning in the 76C10 Course may reduce the number of recycles while having no measureable negative effects and no measureable costs. Of course, reduction of recycles actually lowers training cost by decreasing average residence time at Fort Lee. Research findings were sufficient that Course management recently implemented cooperative learning for all practical exercises in 76C10.

Another reason to introduce cooperative learning is the possible savings in equipment permitted when several soldiers would use the same automated work station for hands-on training. If cooperative learning were in fact used for automated PEs, then the resulting more efficient utilitization of computers would permit automation of instruction beyond simulation of automated job tasks. As discussed above, the QMS school will soon obtain computers sufficient to give each soldier an automated workstation during two weeks out of the planned 12 week Course. Although each individual doing his own work is definitely the Army's preferred mode for hands-on PE's (i.e. to make them as similar to job experience as possible), the advantages of a group learning approach, as cited in the above research with a traditional classroom, are potentially greater in a computer-based environment. For example, if it could be shown that a machine could be used just as well by 4 soldiers at one time, 4 times as many classrooms could be automated (i.e. 12 instead of 3), with a resulting substantial increase in the number of instruction blocks where computers could be considered as tools to shorten training time.

Implementation

The cost effectiveness methodology presented above attempts to expand the practical domain for evaluation of computer applications in Army classrooms. Its focus on training as a production process highlights the period of time, toward the end of an instructional block, when productivity is relatively low and cost per soldier relatively high. This is also the period of time when current policy (for classroom automation) calls for the application of computers for hands-on simulation of automated job tasks. This consistency in focus permits description of future automation options as marginal extensions of hands-on technology.

Current automation policy lowers costs for instructional technology that takes advantage of hands-on hardware and software. It lowers costs because these add-ons to hands-on technology need incur only incremental costs for the software development. The same add-on technology also entails less cost for experimental research to test its effectiveness, and less disruption of normal classroom activities to conduct necessary experiments, because the new computer applications are more or less marginal extensions of what is already being done.

The cost effectiveness methodology helps to plan this incremental development process by targeting instruction blocks and hours within these blocks that offer the greatest cost savings from automation. These savings obtain from reduction in programmed training time or reduction in recycles. Both changes reduce required training time, although the recycle rate and the related dropout rate may be valued as instructional goals quite apart from cost. Since Course length drives over 95% of training cost, reduction of required training time may offset costs incurred to expand computer-based instruction.

This potential for offsetting automation costs, with the time and cost savings that obtain by increasing productivity, recalls the analogy to computer-based equipment simulators (see above). The latter have demonstrated cost effectiveness by reducing the amount of time that must be spent using more expensive actual equipment. Savings resulting from classroom automation involve a more complex series of adjustments in training process, but the argument is made that the current relatively small share of technical training, in total training costs, creates economic leverage for new instructional technology. If experimental research shows that new technology can reduce training time, then the methodology can target investment in new technology in order to maximize savings in time and cost. This approach to cost savings should be compared to present attempts to meet tightening budget constraints by reducing training staff.

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